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Subject:	Fwd: Foillow up to DSC meeting discussion of Delta Eutrophication and N/P ratio
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Subj: Foil low up to DSC meeting discussion of Delta Eutrophication and N/P ratio

Joe, I am contacting you to provide the members of DSC with information on significant deficiencies in C. Dahm's discussion of the literature pertinent to Delta nutrient eutrophication issues and in particular, on the nutrient N/P ratio approach for assessing the impact of nutrients on Delta fish resource management. As documented in our previous comments on the staff draft DSC plans, important literature on these issues has been ignored by the DSC staff in updating the versions of the Plan; again today, C. Dahm's discussion neglected to include a number of key issues and findings reported in the technical literature. It was clear from the discussion of these issues this morning that the DSC remains unaware of substantial professional literature by experts on these issues.

Background to the attached comments is provided on our website www.gfredlee.com where many of the approximately 1100 papers and reports that we have developed over the past six decades on water quality management issues – including eutrophication and aquatic plant nutrients – are available. Our website also makes available more than 120 papers and reports that we have developed during our 20 years of work specifically on Delta water quality issues. As discussed in the attached comments, the March 2008 CWEMF Delta Nutrient Workshop presentations by experts on Delta nutrient water quality issues provide an important resource for technical information and perspective on Delta eutrophication issues of which the DSC should be made aware.

Further, Glibert's position, based on her statistical approach, that N/P ratios are an important factor in influencing Delta fish populations has been found by a number of Delta ecosystem experts to be technically unreliable.

I request that you specifically bring these comments to the attention of DSC and indicate that I will be happy to answer questions on these issues.

Fred

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Comments on the Adequacy of C. Dahm's Discussion of
Delta Eutrophication Issues & Delta N/P Ratios as a
Cause of Adverse Impact on Delta Fish

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November 17, 2011

At today's Delta Stewardship Council public meeting, there was considerable discussion of Delta eutrophication water quality/resource issues and the impact of N/P ratios in the Delta as presented in Glibert et al.'s recent paper:

> Glibert, P. M., D. Fullerton, J. M. Burkholder, J. C. Cornwell and T. M. Kana. 2011. Ecological stoichiometry, biogeochemical cycling, invasive species, and aquatic food webs: San Francisco Estuary and comparative systems. Reviews in Fisheries Science 19:4, 358-417.

The current DSC staff draft versions of the Plan and C. Dahms's presentation today continue to fall significantly short of reliably and adequately informing the DSC on the professional literature on these issues.

In our comments on the third draft of the DSC Plan,

> Lee, G. F., and Jones-Lee, A., "Comments on the Delta Stewardship Council's Third Staff Draft Delta Plan – Chapter 6 Improve Water Quality to Protect Human Health and the Environment – Released April 22, 2011," Submitted to Delta Stewardship Council, Sacramento, CA, Report of G. Fred Lee & Associates, El Macero, CA, Updated May 1 (2011). http://www.gfredlee.com/SJR-Delta/DSCThrdStaffDraft-Com.pdf

we reported the following:

"*Impact of N/P Ratios on Delta Aquatic Life Resources*

The DSC third staff draft Chapter 6 devotes considerable attention to the writings that discuss N/P ratios in the Delta as a cause of ecosystem changes, the pelagic organism decline (POD), and of other resource problems in the Delta. The third staff draft Chapter 6 fails to mention a number of technical issues related to that concern that are discussed in the literature. For example, in his presentation cited below, Cloern discussed the lack of technical validity in the Glibert's claim that changes in N/P ratio are a cause of changes in the Delta ecosystem that has occurred in recent years.

> *Cloern, James "Historical Perspective on Human Disturbance in the Sacramento-San Joaquin Delta Ecosystem", Senior Research Scientist, U.S. Geological Survey Menlo Park, CA presented at National Academies of Science (NAS) National Research Council (NRC) meeting, "Sustainable Water and Environmental Management in the California Bay-Delta" held on July 13-15, 2010 in Sacramento, Ca, PowerPoint slides obtained from the NRC Public Access Records Office at www.nrc.gov/reading-rm/foia/foia-privacy.html.*

In his CWEMF nutrient workshop presentation entitled, "Impact of Sacramento River Input of Phosphorus to the Delta on Algal Growth in the Delta," Dr. Erwin Van Nieuwenhuyse summarized his recent paper describing the response of average summer chlorophyll concentration in the Delta to an abrupt and sustained reduction in phosphorus discharge from the Sacramento County Regional Sanitation District wastewater treatment facility. His presentation provides important information on the impact of Sac Regional phosphorus discharge on Delta planktonic algae in the Delta, and is available at, http://www.cwemf.org/workshops/DeltaNutrientsWrkshp/VanNieuwenhuyse.pdf."

In our comments on the fifth draft DSC staff Plan,
Lee, G. F., and Jones-Lee, A., "Comments on the DSC Staff Fifth Draft of Chapter 6 Devoted to Delta Water Quality Issues in the Delta Plan," Comments Submitted to Delta Stewardship Council, Sacramento, CA, by G. Fred Lee & Associates, El Macero, CA, August 21 (2011). http://www.gfredlee.com/SJR-Delta/DeltaPlan5DraftCh6Comm.pdf

on *Page 142 line 27 and following: In our comments on technical deficiencies in the third staff draft Chapter 6 (cited above) we stated,*
"The California Water Environmental Modeling Forum (CWEMF) develops peer reviews of modeling approaches and develops workshops on water modeling issues; Dr. Lee was asked to serve as a member of the CWEMF steering committee. With Dr. Jones-Lee he developed for the CWEMF a workshop entitled, "Overview of Delta Nutrient Water Quality Problems: Nutrient Load - Water Quality Impact Modeling," which was presented to an audience of about 100 in March 2008. Information on that workshop is available on the CWEMF website [http://www.cwemf.org] at:
http://www.cwemf.org/workshops/NutrientLoadWrkshp.pdf. Additional information on the workshop is available at:

> *Lee, G. F., and Jones-Lee, A., "Delta Nutrient-Related Water Quality Problems," PowerPoint Slides Presented at CALFED Science Conference, Sacramento, CA, October 24 (2008). http://www.gfredlee.com/SJR-Delta/CALFED_SciConf10-08.pdf*
>
> *Lee, G. F., and Jones-Lee, A., "Synopsis of CWEMF Delta Nutrient Water Quality Modeling Workshop – March 25, 2008, Sacramento, CA," Report of G. Fred Lee & Associates, El Macero, CA, May 15 (2008).*
> *http://www.gfredlee.com/SJRDelta/ CWEMF_WS_synopsis.pdf*
>
> *"Overview of Delta Nutrient Water Quality Problems: Nutrient Load – Water Quality Impact Modeling," Agenda for Technical Workshop sponsored by California Water and Environmental Modeling Forum (CWEMF), Scheduled for March 25, 2008 in Sacramento, CA (2008).*
> *http://www.gfredlee.com/SJR-Delta/CWEMF_Workshop_Agenda.pdf*
>
> *Lee, G. F., and Jones-Lee, A., "Delta Nutrient-Related Water Quality Problems," PowerPoint Slides Presented at CALFED Science Conference, Sacramento, CA, October*

As noted in our review of DSC third draft Chapter 6 the work of Dr. Van Nieuwenhuyse should be mentioned at this location in Chapter 6. We stated in our comments on the third staff draft of Chapter 6:

"In his CWEMF nutrient workshop presentation entitled, "Impact of Sacramento River Input of Phosphorus to the Delta on Algal Growth in the Delta," Dr. Erwin Van Nieuwenhuyse summarized his recent paper describing the response of average summer chlorophyll concentration in the Delta to an abrupt and sustained reduction in phosphorus discharge from the Sacramento County Regional Sanitation District wastewater treatment facility. His presentation provides important information on the impact of Sac Regional phosphorus discharge on Delta planktonic algae in the Delta, and is available at, http://www.cwemf.org/workshops/DeltaNutrientsWrkshp/VanNieuwenhuyse.pdf.

"As discussed in the van Nieuwenhuyse workshop presentation and published paper,

> *vanNieuwenhuyse, E., "Response of Summer Chlorophyll Concentration to Reduced Total Phosphorus Concentration in the Rhine River (Netherlands) and the Sacramento–San Joaquin Delta (California, USA)," Can. J. Fish. Aquatic, Sci. 64(11):1529-1542 (2007).*
> *[http://www.ingentaconnect.com/content/nrc/cjfas/2007/00000064/00000011/art00006]*

and the Lee and Jones-Lee workshop presentation, backup information, and papers referenced in their presentations, it is well-established that reducing the phosphorus loads and in-waterbody concentrations effects reductions in the phytoplankton biomass in Delta waters. This occur even in situations in which the available phosphorus concentrations in the waterbody remain surplus compared to growth-rate-limiting concentrations. The decrease in planktonic algae in the Delta associated with decreased phosphorus loads to the Delta is important information that must be discussed in a creditable discussion of the impact of nutrients on Delta water quality.

The changes in the Delta ecosystem that occurred associated with Sac Regional decreased phosphorus discharges rather than the change in N/P ratios as discussed in the DSC staff third draft are a more likely cause of changes in the fish production than the change in the N/P ratios discussed by the staff in the third draft."

In our comments on the fourth draft of Chapter 6

> Lee, G. F., and Jones-Lee, A., "Comments on Revised Delta Plan Staff Draft Chapter 6 'Improve Water Quality to Protect Human Health and the Environment' as Presented in the Fourth Staff Draft of the Delta Plan," Comments Submitted to Delta Stewardship Council, Sacramento, CA, by G. Fred Lee & Associates, El Macero, CA, June 14 (2011).
> http://www.gfredlee.com/SJR-Delta/DeltaPlan4DraftCh6Comm.pdf

we stated,

"Impact of N/P ratios

We discussed the inadequate coverage of the issue of the impact of N/P ratios on Delta aquatic life resources (beginning on page 21 of our comments on the third staff draft). The fourth staff draft discussion has been expanded to include the reference to the report by Cloern on this issue that we noted in our comments. However the revised Chapter 6 fails to mention a very important *reference to the work of Dr. Erwin Van Nieuwenhuyse on phosphorus reduction issues, also noted in our previous comments."*

"The importance of nutrients as a cause of water quality problems in the Delta is discussed in the revised third staff draft, now the fourth staff draft of Chapter 6. While considerable information on these problems is provided in the revised chapter, the draft fails to discuss and provide adequate reference to the most comprehensive review of the nutrient issues, i.e., the 2008 CWEMF Delta Nutrient workshop. Nutrient issues were discussed in our comments on the third staff draft, from page19 through part of page 21. The 2006 reference provided in the fourth staff draft to an outdated DWR report on nutrient issues is not adequate for providing the reader with current information on Delta nutrient water quality issues that need to be addressed. Of particular concern is the impact of nutrients on drinking water quality and the potential for controlling nutrients and their impacts. The fourth staff draft Chapter 6 continues to provide recommendations to the CVRWQCB on when it should develop nutrient criteria. We discussed the unreliability of recommendations pertaining to nutrients in our comments on the third staff draft."

In the fourth, and now the fifth, draft of Chapter 6, the draft Delta Plan still fails to mention or provide reference to the work of Dr. van Nieuwenhuyse on the potential role of phosphorus in impacting phytoplankton populations in the Delta and the failure to mention the CWEMF Delta nutrient workshop represents a fundamental flaw in how the DSC staff have reviewed and incorporated information provided by DSC draft plan reviewers in revisions of the Plan.?

The bottom line is that there was considerable information provided in the Workshop presentations by experts on Delta nutrient water quality issues (available on the CWEMF website) that has not been properly incorporated into the Plan or discussions of the issues before the DSC. Furthermore, the unreliability of the Glibert, et al. N/P ratio approach for assessing the impacts of nutrients on Delta fish populations has been addressed by internationally recognized experts on the Delta ecosystem, including in the following paper (a preprint copy of which is attached):

> James E. Cloern, Alan D. Jassby, Jacob Carstensen, William A. Bennett, Wim Kimmerer, Ralph Mac Nally, David H. Schoellhamer, Monika Winder, "Perils of correlating CUSUM-transformed variables to infer ecological relationships (Breton et al. 2006, Glibert 2010)," in press.

As discussed in my comments on the third staff draft of the Plan, Cloern, an international recognized expert on Delta ecosystem issues, also reported on this issue at a National Academy of Science (NAS)–National Research Council (NRC) meeting, "Sustainable Water and Environmental Management in the California Bay-Delta," held on July 13-15, 2010 in Sacramento, CA. At that meeting Cloern explicitly stated that Glibert's approach for evaluating the impact of N/P ratios on Delta fish is not technically valid.

The disregard of technical information and comments provided in this process, and the narrow focus on technically invalid approaches are of great concern if the goal of this process is to provide the DSC with reliable and complete technical information concerning the impacts of nutrients on Delta water quality. If there are questions of comments on these comments please contact me.

Fred

L&O 11-105 27 April 2011

Perils of correlating CUSUM-transformed variables to infer ecological relationships (Breton et al. 2006, Glibert 2010)

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Suggested citation:
Cloern, J.E., A.D. Jassby, J. Carstensen, W.A. Bennett, W. Kimmerer, R. Mac Nally, D.H. Schoellhamer and M. Winder. 2011. Perils of correlating CUSUM-transformed variables to infer ecological relationships (Breton et al. 2006, Glibert 2010). Limnology and Oceanography, in press.

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We comment on a nonstandard statistical treatment of time-series data first published by Breton et al. (2006) in Limnology and Oceanography and, more recently, used by Glibert (2010) in Reviews in Fisheries Science. In both papers, the authors make strong inferences about the underlying causes of population variability based on correlations between cumulative sum (CUSUM) transformations of organism abundances and environmental variables. Breton et al. (2006) reported correlations between CUSUM-transformed values of diatom biomass in Belgian coastal waters and the North Atlantic Oscillation, and between meteorological and hydrological variables. Each correlation of CUSUM-transformed variables was judged to be statistically significant. On the basis of these correlations, Breton et al. (2006) developed "the first evidence of synergy between climate and human-induced river-based nitrate inputs with respect to their effects on the magnitude of spring *Phaeocystis* colony blooms and their dominance over diatoms."

Using the same approach, Glibert (2010) reported correlations between CUSUM-transformed abundances of organisms occupying many trophic levels and a range of environmental variables in the San Francisco Estuary, California. These correlations were reported to be statistically significant, and on this basis Glibert (2010) concluded that recent large population declines of diatoms, copepods and several species of fish were responses to a single factor – increased ammonium inputs from a municipal wastewater treatment plant. The study by Breton et al. (2006) is consistent with a large body of research demonstrating the importance of climate and human activity on phytoplankton communities in Belgian coastal waters (Lancelot 2007). However, Glibert's (2010) study piqued our curiosity about correlations between CUSUM-transformed variables because it contradicts the overwhelming weight of evidence that population collapses of native fish (Sommer et al. 2007) and their supporting food webs in the San Francisco Estuary are responses to multiple stressors including landscape change, water diversions, introductions of exotic species, and changing turbidity (Bennett and Moyle 1996; Kimmerer et al. 2005; Cloern 2007; Jassby 2008; Mac Nally et al. 2010; Thomson et al. 2010). We ask here how CUSUM transformation leads to inferences about such cause-effect relationships when visual inspection of the data series (e.g., Fig. 1) shows no association between wastewater ammonium and fish abundance.

We emphasize an important distinction between the CUSUM chart and CUSUM transformation. The CUSUM chart is a well-established technique of quality assurance for industrial processes (Page 1954). The method involves keeping a running summation of the deviations of the quality of the quantity of interest (e.g., concentration of an industrial chemical) based on a sample of size *n*. If the quantity suddenly jumps, or gradually drifts from the specified tolerance, then a warning is raised and the process is stopped. The CUSUM chart has been used as a valuable off-line method in aquatic sciences to detect and resolve climatic (Breaker 2007) and ecological (Briceño and Boyer 2010) regime shifts, as well as departures of water-quality indicators from compliance conditions (Mac Nally and Hart 1997). In contrast, there appears to be no history for regression (or correlation) analyses on CUSUM-transformed variables prior to its use by Breton et al. (2006), and we have found no theoretical development or justification for the approach. We prove here that the CUSUM transformation, as used by Breton et al. (2006) and Glibert (2010), violates the assumptions underlying regression techniques. As a result, high correlations may appear where none are present in the untransformed data (e.g., Fig. 1). Regression analysis on CUSUM-transformed variables is, therefore, not a sound basis for making inferences about the drivers of ecological variability measured in monitoring programs.

This issue is sufficiently important to warrant exploration of the approach, which we present here.

The CUSUM function

The CUSUM function is a mathematical discrete operator that transforms an input time series (x_t) to an output time series (y_t) representing the running total of the input.

$$y_t = \sum_{i=1}^{t} x_i \tag{1}$$

The CUSUM function often is applied to time series of standardized residuals to detect changes in the mean of the time series (Zeileis et al. 2003; Breaker 2007). The CUSUM function changes the statistical properties of the input time series. If the standardized input time series consists of independent observations with zero mean ($E[x_t] = 0$) and variance σ^2 ($V[x_t] = \sigma^2$) then

$$E[y_t] = \sum_{i=1}^{t} E[x_i] = 0 \tag{2}$$

$$V[y_t] = \sum_{i=1}^{t} V[x_i] = t \cdot \sigma^2 \tag{3}$$

$$Cov[y_t, y_{t-1}] = Cov\left[\sum_{i=1}^{t} x_i, \sum_{i=1}^{t-1} x_i\right] = (t-1) \cdot \sigma^2 \tag{4}$$

$$Corr[y_t, y_{t-1}] = \frac{Cov[y_t, y_{t-1}]}{\sqrt{V[y_t] \cdot V[y_{t-1}]}} = \frac{(t-1) \cdot \sigma^2}{\sqrt{t \cdot \sigma^2 \cdot (t-1) \cdot \sigma^2}} = \frac{t-1}{\sqrt{t \cdot (t-1)}} \tag{5}$$

This means that the variance of the CUSUM-transformed variables and the autocovariance between two consecutive observations of the CUSUM-transformed variables both grow linearly with time and, consequently, the autocorrelation of the CUSUM-transformed variables quickly approaches 1.

Two key assumptions behind tests derived from standard regression analyses are that the observations comprising the sample are independently and identically distributed (IID). As shown above, both assumptions are violated when a random input variable is CUSUM-transformed because: the variance is not constant, so the transformed observations are not identically distributed; and the transformed observations are autocorrelated and therefore not independent of one another. Thus, applying statistical regression techniques to CUSUM-transformed time series violates the two most crucial assumptions for these tests.

CUSUM transformation inflates correlation

The CUSUM of a purely random process is a pure random walk, an example of a difference-stationary variable (because its first difference is stationary). Pfaff (2006) described the difficulty of using difference-stationary variables in regression and correlation: "In this case, the error term is often highly correlated and the t and F statistics are distorted such that the null hypothesis is rejected too often for a given critical value; hence the risk of a 'spurious regression' or 'nonsense regression' exists. Furthermore, such regressions are characterized by a high R^2." Regressions involving cumulative variables such as those produced by CUSUM transformation are classic examples of spurious regression and a well-known problem in econometrics (Hendry 1980).

To illustrate the problem more concretely, we conducted the following Monte Carlo experiment. We first generated two independent, standardized (mean 0, standard deviation 1), normal random processes of length 30, about the length of many annualized time series available from monitoring data (e.g., those analyzed by Glibert 2010). We then calculated the Pearson correlation between these two series and also between their CUSUM-transformed values. We repeated the process 100,000 times, yielding two distributions of correlation coefficients from which we generated 95% confidence intervals (CI). The distribution of CUSUM correlations is very different from the distribution of correlations of the untransformed variables (Fig. 2). The 95% CI is (-0.36, 0.36) for the original variables (Fig. 2A), but (-0.71, 0.71) for the CUSUM-transformed variables (Fig. 2B). Thus, correlations must exceed 0.71 (instead of 0.36) for CUSUM-transformed variables to be considered significant at the $p < 0.05$ levels. This implies that the CUSUM transformation increases the probability of making a Type I error (incorrectly rejecting a null hypothesis of no correlation) from 5% to 42% when Pearson's statistics are applied. Therefore, on this basis alone, the *p*-values for correlations of CUSUM-transformed variables reported by Breton et al. (2006) and Glibert (2010) are incorrect.

The above experiment was based on independent random processes. Water resources data, however, commonly exhibit serial correlation (Helsel and Hirsch 2002). The introduction of serial correlation accentuates the problem by broadening the distribution of correlation coefficients even further than in the example above. To measure this effect, we repeated the simulations after introducing varying amounts of first-order serial correlation (r_1, r_2) into the paired series that otherwise represented random normal processes (using the *arima.sim* function of R; R Development Core Team 2010). This second experiment shows how the 95% CIs for the correlations broaden in proportion to the strength of serial correlation (Table 1, Fig. 2C). The presence of serial correlation thus increases the probability of making a Type I error further (53% when $r_1 = r_2 = 0.5$), making any conclusions from such correlations correspondingly less reliable. Even if a significance level of $p < 0.0001$ were used, the probability of making a Type I error (19% when $r_1 = r_2 = 0.5$) would still be much greater than 5%.

We showed that two CUSUM-transformed variables often have an apparent statistically significant correlation even if none exists between the original untransformed series. Moreover, even if a statistically significant relationship could be established between CUSUM-transformed variables, there is no proven basis for inferring relationships between the original variables. Given these difficulties, we wonder what purpose is served by CUSUM transformation for exploring relationships between two variables. As a real example, Glibert (2010) inferred a strong negative association between delta smelt abundance and wastewater ammonium from regression of CUSUM-transformed time series. However, the Pearson correlation (r = -0.096) between the time series (Fig. 1) is not significant, even under the naive IID assumptions (p = 0.68). In short, correlations between CUSUM-transformed variables should not be used as a substitute for analysis of the original untransformed variables.

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Table 1. Upper limits of the 95% CIs for correlation between two untransformed and CUSUM-transformed random variables with different combinations of serial correlation coefficients, r_1 and r_2.

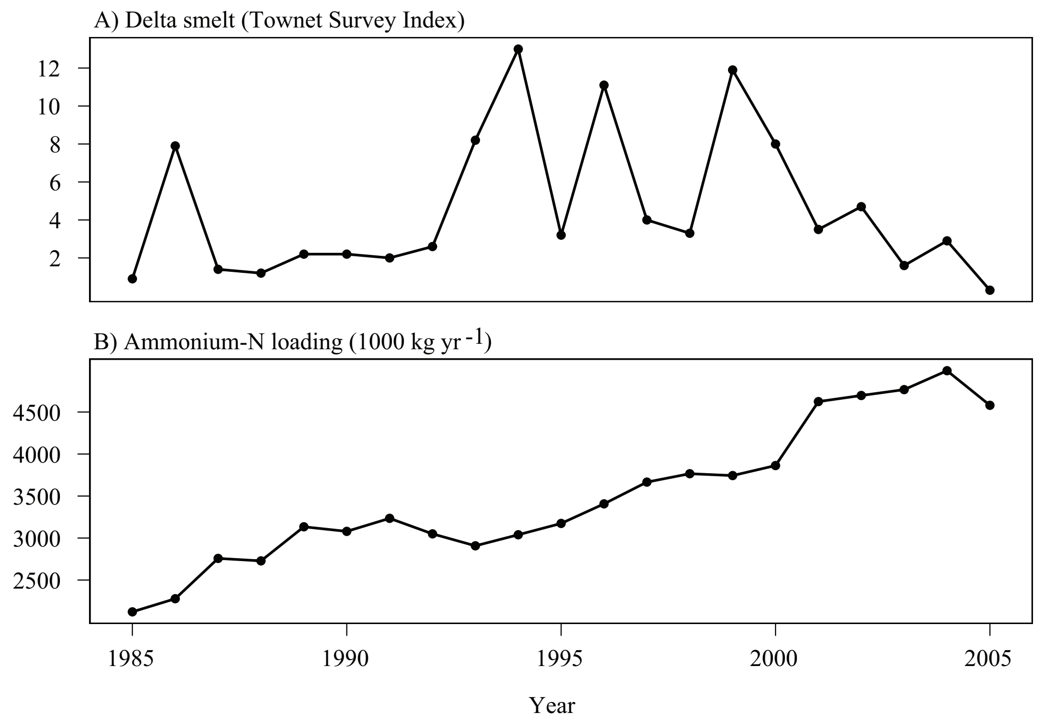
r_1	r_2	Untransformed	CUSUM-transformed
0.0	0.0	0.36	0.71
0.1	0.1	0.36	0.73
0.1	0.5	0.38	0.77
0.1	0.9	0.39	0.82
0.5	0.5	0.44	0.81
0.5	0.9	0.51	0.86
0.9	0.9	0.71	0.92

Figure Legends

Figure 1. Annual (A) abundance index of delta smelt (*Hypomesus transpacificus*) in the San Francisco Estuary and (B) wastewater loadings of ammonium to the Sacramento River, 1985-2005. Treatment plant data were obtained from the Sacramento Regional County Sanitation District (S. Nebozuk pers. comm., 28 July 2006). Monthly loading was calculated from discharge-weighted ammonium concentrations using the methods described by Jassby and Van Nieuwenhuyse (2005). Delta-smelt abundance data were obtained from the California Department of Fish and Game (http://www.dfg.ca.gov/delta/data/townet/indices.asp?species=3).

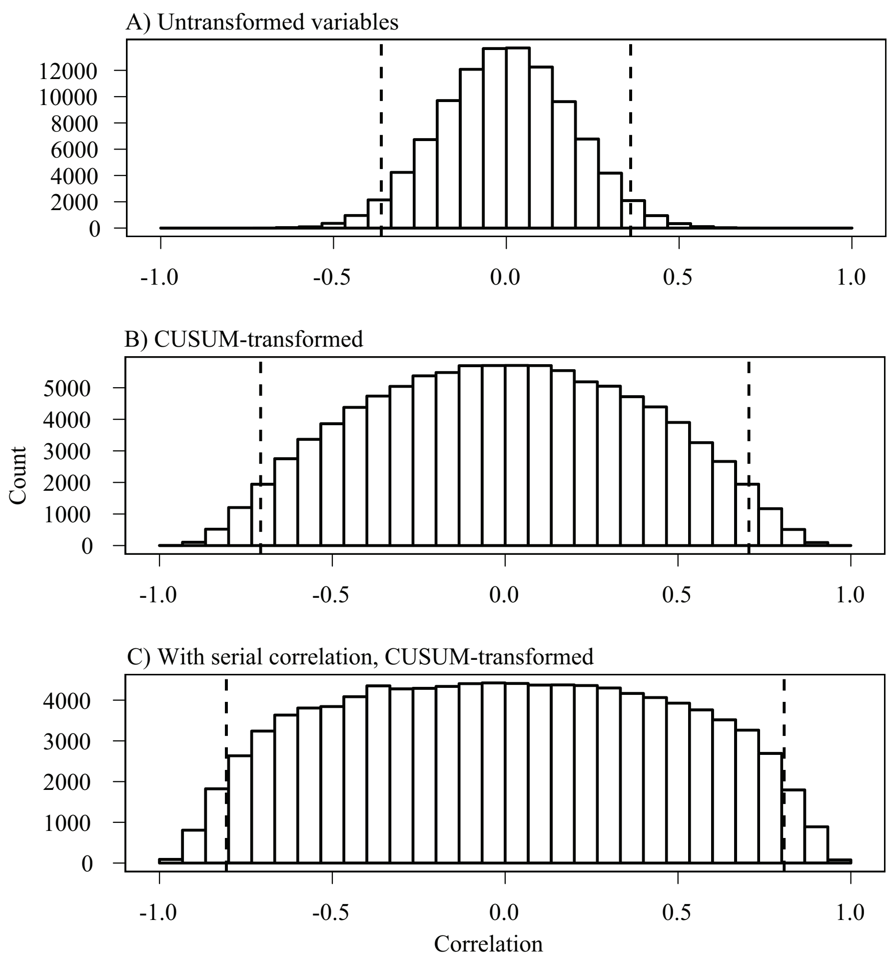
Figure 2. (A) Frequency distribution of correlation coefficients for two independent random normal series of length 30 (n = 100,000). (B) Same as A after the samples are CUSUM-transformed. (C) Same as B, but with first-order serial correlation of 0.5 introduced into the otherwise random normal processes. Vertical dashed lines, 95% CI.

Fig 1



A) Delta smelt (Townet Survey Index)
12
10
8
6
4
2
B) Ammonium-N loading (1000 kg yr -1)
4500
4000
3500
3000
2500
1985
1990
1995
2000
2005
Year

Fig 2


A) Untransformed variables
12000
10000
8000
6000
4000
2000
0
-1.0
-0.5
0.0
0.5
1.0
B) CUSUM-transformed
Count
5000
4000
3000
2000
1000
0
-1.0
-0.5
0.0
0.5
1.0
C) With serial correlation, CUSUM-transformed
4000
3000
2000
1000
0
-1.0
-0.5
0.0
0.5
1.0
Correlation

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